# Climate Observation Program Workshop
# Focus on the Ocean

## 13-15 May 2003
## Silver Spring, Maryland

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Sponsored by:
The NOAA Office of Global Programs

**Workshop Report**

Workshop web site URL:
http://www.ogp.noaa.gov/mpe/co/meeting/co_5_03/index.html

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# Executive Summary

### *Background*

In January 2003, the NOAA Climate Program Office and the Office of Global Programs jointly established a new Project Office for Climate Observation (OCO) to provide an organizational framework for advancing NOAA's contributions to the global climate observing system. The projects existing within the Climate Observation Program were to provide the initial building blocks.

The mission of the OCO is to build and sustain a global climate observing system that will respond to the long-term requirements of the operational forecast centers, international research programs, and major scientific assessments. The initial focus is to monitor, evaluate, and evolve the ocean networks, adding the atmospheric networks as soon as possible. In order to help chart the plan of action for the new OCO, the Climate Observation Program Workshop was held 13-15 May 2003. The primary objectives of the workshop were to design a framework for regular reports on both the state of the ocean and the adequacy of the ocean observing system for climate, institute an annual Project Managers (PI) meeting, and design a framework for implementing Expert Teams to continually evaluate the quality and effectiveness of the observing system. This report recommends strategies for the design of the Annual Report to define current and future climate observation needs.

Delivery of an *Annual Report on the State of the Ocean and the Ocean Observing System for Climate* will address one component of the National Climate Change Science Program's (CCSP) strategic plan identifying the critical need for regular reports documenting the present state of the climate system components. The theme of the report will address the CCSP overarching question: "What is the current state of the climate, how does it compare with the past, and how can observations be improved to better initialize and validate models for prediction or long-term projection?"

Because there are about 40 projects contributing to the existing Program, the need exists for an efficient way to communicate about the ongoing activities. The Annual Report will satisfy that need.

It is also suggested that the Report serve as a system-organizing framework to inform both scientists and non-scientists with a direct linkage to end-users. The Annual Report will define individual project outcomes, identify system needs, and establish the foundation for future program growth.

The annual report will present climate products in understandable ways to decision makers, the science community, and the public. At the same time this reporting framework will establish a formal mechanism for implementing a "user-driven" observing system and for reporting on the system's performance in meeting the requirements of the operational forecast centers, international research programs, and major scientific assessments. Stakeholders will be invited to provide formal recommendations for system improvement and evolution as part of the annual report process.

### *Call for Reports*

While science managers of each Program-funded project currently provide annual project reports, a standard format for the report is not used. It was determined that a call for project reports adhering to a common format would be developed and issued during fall 2003 to obtain information from PIs consistent with needs for the Annual Report. This will satisfy the clear need to inform the scientific community, stakeholders, and the public at large about climate observation and the connection to their lives and work.

### *Expert Teams*

Expert teams of scientists must be developed to continually evaluate the quality and limitations of climate products and the effectiveness of the networks in providing the needed data. The expert teams will evaluate analysis/synthesis products, recommend product improvements, recommend where additional sampling is needed or redundancies are not needed, recommend better utilization of existing and new in situ and satellite data, and assess the impacts of proposed changes to the system.

### *Working groups*

Workshop participants separated into working groups based on their areas of expertise and interest.

- Working Group 1: Report structure
- Working Group 2: Sea level
- Working Group 3: Air-sea exchange of heat, water, carbon
- Working Group 4: Ocean content and transport of heat, water, carbon

### *Proposed Chapter Contents*

The workshop recommended that the annual report contain four chapters. A general overview of each chapter is presented below.

1) The first chapter introduces **The Role of the Ocean in Climate**. It provides rationale for the report while generally describing the systems that make up our

oceans and climate. This chapter could include a description of ENSO, SST, sea ice, and sea level, for example, and the various demands of each on the system incorporating the scales of seasonal / interannual vs. decadal vs. climate change. This chapter sets the context for the report and outlines common themes.

2) The second chapter will document the **State of the Ocean**. The target audience will be decision makers and non-scientists. This chapter will be an annually updated climatology of the ocean, placed in historical context, with discussion of the present uncertainties and with pointers to products of greater detail and climate applications.

3) The third chapter will document the **State of the Observing System**. The target audience will be NOAA management. This chapter will have two sections:

    a. System Progress in meeting milestones will be documented by the network managers. Annual statistics and status will be given. This section will essentially be a compilation of the annual reports that program PIs are used to writing.
    b. Overall System Performance will be evaluated by the expert teams and by the users of ocean observations (the operational forecast centers, research programs, and scientific assessments). Stakeholders not sitting on the expert teams (e.g., ECMWF, BoM, JMA, etc.) will also be invited annually to give formal feedback to the observing system management and recommend improvements needed in the observations for delivery of climate services.

4) Chapter four will recap the **State of the Science**. The target audience will be scientists. The final chapter of the report will contain a bibliography of refereed publications from scientific journals treating the global observation of ocean heat, carbon, fresh water, and sea level change. Each year a selected number of reprints of particularly relevant scientific papers and abstracts will be included in the report. Selection will be by the expert teams.

After meeting in each working group, workshop participants recommended a number of alternate plans for the content and structure of each chapter of the Annual Report. These are described in the workshop report following this executive summary.

### ***General timeline and scale of report***

It was recommended that in Year 1 the initial Annual Report be primarily an OGP document used as a management tool with limited distribution. It can be used to spin off other focused reports. Then, the Annual Report will expand and build in subsequent years with annual publication focused at OGP with expansion to NOAA, the United States, and finally global distribution. An end target should be the IPCC.

This Workshop Report provides an overview of the workshop program, outcomes of the meeting, and links to all PowerPoint and poster presentations given by workshop participants. PowerPoint presentations and posters are also available on the OCO website at http://www.ogp.noaa.gov/mpe/co/meeting/co_5_03/index.html.

# Workshop Report

***Overview***[1]

Mike Johnson, Program Manager for Climate Observation, thanked participants and welcomed them to the Workshop intended to help chart the future of the Program. Ken Mooney, Acting Director of the Office of Global Programs (OGP), described the foundation of the Climate Observation Program (leading to development of the OCO) including the mission statement of OGP.

Dave Goodrich, speaking on behalf of Mary Glackin, described the future of the NOAA Climate Program. He stated that the design, implementation, operation and management of a Climate Ocean Observing System should be requirements-based and product driven, recognize related national and international efforts (e.g., IOOS, GODAE, GCOS, GOOS), address end-to-end systems (observation to product generation to archive / access), support detection of needed system changes, and use a system design that allows efficient changes.

**Session 1 – Partnerships and Requirements (Chair: Peter Niiler)**
Tuesday morning, 13 May

Ed Harrison described *The Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC* and expressed the need for better data exchange with international communities, the need to ask how our networks are doing, to learn more about less developed nations, and the need for nations to be informed and to report gaps to UNFCCC. Ocean domain specific recommendations include global coverage and generation of climate products. (See www.wmo.ch/gcos to review report.)

Chet Koblinsky described the *U.S. Climate Change Science Program* (www.climatescience.gov), which merges the USGCRP and the CCRI. He reported that the National Research Council Review is ongoing, with a written review provided at this point. One example of a question that has arisen is, "To what extent can uncertainties in climate change projections due to climate system feedbacks be reduced?" Chet reminded everyone that the Earth Observation Summit will be held in D.C. on 31 July 2003 with international government and NG leaders in climate science, technology and the environment participating.

After brief discussion and a short break, Eric Lindstrom gave a presentation on planning for *the Integrated Ocean Observing System* (IOOS) with Ocean.US. Creating an IOOS falls within the structure of the National Oceanographic Partnership Program (NOPP), created by Congress, to help the 14+ agencies involved in the ocean more effectively address common issues. The IOOS is guided by the National Ocean Research Leadership

[1] All participants' PowerPoint presentations and posters are available on this CD. See Appendix A & B.

Council and coordinated within the Ocean.US, while anticipating the recommendations of the Commission on Ocean Policy and expecting action by the Legislative and Executive branches.

Michael Neyland reported for Rob Mairs on the *NOAA Observing System Architecture* (NOSA) with results showing 100 observing systems measuring 408 environmental parameters, and with 29,000 observation platforms in place that are NOAA-controlled. NOAA's observational architecture is defined as the composition of NOAA's observing systems and other observing systems required to support NOAA's mission, the relationship among observing systems, and the guidelines governing the design of a target architecture and the evolution to this target architecture

Stan Wilson presented *Policy-Relevant Questions for the Observing System*. He reported on Argo status; starting in FY99, 770 floats of the 3,000-float global array are now in place and operating. Funding is coming from 14 nations and EC at a rate sufficient to complete the array in ~2006. He stated the major challenges and lessons learned from Argo as well as the need for a consensus set of policy-relevant questions of fundamental scientific importance to address climate.

Bob Weller reported on the *NSF Ocean Observatory Initiative* (OOI), a five-year project planned at $200 million for coastal and blue water observations. Funding is to provide the infrastructure. Continuing science utilizing the OOI infrastructure has to be funded separately.

Silvia Garzoli described the *South Atlantic Climate Observing System Workshop*, held 6-8 February 2003 in Brazil. The SACOS workshop was motivated by the belief that the South Atlantic circulation influences, directly or indirectly, the variability of the regional and global climate. Few observations are made in the South Atlantic compared with the Northern Hemisphere. Silvia described some of the current and future instrumentation placed in the Atlantic by different countries.

After lunch, Michael McPhaden discussed an *Indian Ocean Observing System Workshop* and progress toward efforts instrumenting that part of the world. There is increasingly organized activity there because of compelling unanswered questions, clear impacts if we can forecast for that area, the fact that Indian rim nations are spending more, and it is a very poorly sampled part of the world. Models show that the Indian Ocean may even influence the NAO. Some of the challenges include array designs, funding, deployment platforms, measurement standards, fishing vandalism, data access and management, and international coordination and partnerships.

Shawn Smith described the *High Resolution Meteorology Data Workshop*, held 3-5 March 2003. Many recommendations were presented including development of a sustained system of calibrated, quality-assured marine meteorological observations built around the surface flux reference sites, drifting buoys, research vessels (RVs), and volunteer observing ships (VOS) to support science objectives of national and international climate programs. It was also suggested that sources / contacts be established where expertise can be obtained by operators and made available for QA development.

Yan Xue described the *Seasonal Forecasting Priorities for the Observing System* and a series of forecast modeling schemes. Needs for intraseasonal and seasonal forecasting include extending the mooring lines at 110°W and 125°W, adding a mooring line just off the west coasts of South and Central America, and sustained observations in the North and South Pacific.

The final speaker before an afternoon break was Tom Delworth. He spoke about *Decadal Forecasting Priorities for the Observing System*. Modeling is used to provide output for decadal predictability. One recent study predicts that the NAO is more likely to be positive than negative in the next couple of years, followed by negative NAO in the following years. In order for decadal forecasts to have meaning, there is a need to demonstrate potential predictability, assess utility of such predictability, identify appropriate forecast models, and collect sufficient observations to make forecasts. Modeling studies have shown a meaningful level of Atlantic oceanic decadal predictability.

## Session 2 – Annual Report (Chair: Diane Stanitski)

Tuesday afternoon, 13 May

Mike Johnson described the Annual Report as a system-organizing framework to enable "smart sampling" and to inform scientists, non-scientists, and decision makers about the state of the ocean and the adequacy of the observing system. There is a need for regular review of the Program and a report documenting the accomplishments, future plans, and needs for expansion of the Program. Knowledge of system performance will lead to evaluation and feedback. Discussion followed about how and where the document would be published.

Tom Karl presented the National Climatic Data Center's (NCDC) annual climate assessment as a possible model for the ocean report. The development of the NCDC report helped obtain a new perspective on performance of the observing system, and requires a major effort in people, processes, and databases. Resistance was experienced at first but support grew through time. The Office of Climate Observation Report will not be as comprehensive to start, but will develop through time. It needs to be complete and authoritative in order to lend credibility. Cost of this process is justified because scientific stewardship is part of NOAA's mission.

Discussion ensued about the possible structure and development of the annual report. The process will be iterative, as we learn from the initial outcome. It is important to present this as a climate contribution to the global climate observing system. Uncertainties will be documented to justify enhancements. Progress can be compared relative to requirements of the system.

Although no final decisions regarding the report were made, all recommendations were documented and discussion tabled to the following day.

Session 2 concluded with a poster session and evening reception. Because there are 40 funded projects in the existing OCO, each PI was asked to create a poster and associated PowerPoint slides for their project to be made available at the workshop and on the OCO web site, and as posters in a poster session at the meeting (See Appendix A and B.).

## Session 3 – Expert Teams and the Annual Report (Chair: Ed Sarachik)

Wednesday morning, 14 May

Based on the variety of priorities and ideas presented during Session 2 discussion, the program agenda was revised to enable more time for plenary discussion before moving to breakout groups.

The NESDIS publication "Treasures at Risk" comes out every two years and has a stoplight chart for NOAA scientific data stewardship showing things we can do right now and things that need additional support. This could be used as background for the OCO Annual Report.

Michele Reinecker of ODASI expressed the need for a dense network of ocean observations, essential for understanding and improving models. Complementary data and cross-validation is requested whenever possible to validate the models and improve understanding.

### Expert Teams

Discussion followed regarding the establishment of "expert teams" of scientists to continually evaluate the skill and limitations of climate products and the effectiveness of the networks in providing needed data. Expert teams will evaluate analysis/synthesis products, recommend product improvements, recommend where additional sampling is needed or redundancies are not needed, recommend better utilization of existing and new *in situ* and satellite data, and assess the impacts of proposed changes to the system.

<u>Straw man topics for expert teams (observational vs. thematic):</u>

The straw man framework presented for discussion included expert teams to focus on:

- Seasonal Forecasting
- Decadal Forecasting
- Sea Level Change
- Carbon Sources and Sinks
- Air-sea exchange of heat and water
- Ocean content and transport of heat and fresh water
- SST
- Sea Ice

## Annual Report

The goals for the Annual Report include smart sampling, organization of a framework for program direction of the Office of Climate Observation, and use as an enabling mechanism to present climate products to decisions makers, the science community, and the public. Ideas include discussion of the present state of the global ocean, how it compares with the past, and the confidence/uncertainty in the data and products used to describe the state of the ocean.

Kevin Trenberth led a plenary discussion on expert teams and the structure of the annual report. The following working groups met to design the annual report.

| | Chaired by: |
|---|---|
| Group 1: Report structure | Kevin Trenberth |
| Group 2: Sea level | Bruce Douglas |
| Group 3: Air-sea exchange of heat, water, carbon | Bob Weller |
| Group 4: Ocean content & transport of heat, water, carbon | Bob Molinari |

The working groups reconvened in plenary and presented the results of the working group sessions for discussion. Each working group's PowerPoint presentation can be accessed through Appendix D-4.

## WORKING GROUP DISCUSSION RESULTS

### *GROUP 1: REPORT STRUCTURE (Chair: Kevin Trenberth)*

This working group felt that a primary goal of the report is for accountability purposes to determine how Program money is spent for each of the 40 funded projects. The report serves as a synthesis for assessment of the Program.

The proposed title is ***The State of the Ocean and the Ocean Observing System for Climate***. The report should be designed as a tool to inform about the possibilities for the observing system five years from now.

The report might include four chapters. It should be recognized that doability with the proposed timeline should be considered; the report can build and does not need to be comprehensive in the first year; its importance is in helping manage the global observing system and for program accountability.

Recommendations included using the Monthly Diagnostics Bulletin summary as a template – it is both doable and meaningful.

Group 1 Recommendations:

The annual report is for management and should report on and include:

- Components of the observing system
- Uses of data
- Enabled products
- Issues: ship time needs, gaps, etc
- Data management, access, archival
- International context
- Collaborations
- Papers

PIs should answer the following questions in their reports:

1. What do you know?
2. What don't you know?
3. What is not working?
4. What are your needs?

Concerns:

- What incentives are there to provide information from those not funded by NOAA?
- System performance?

***Chapter 1: Introduction on the Role of the Ocean in Climate***

This chapter could include a description of ENSO, SST, sea ice, and sea level, etc., and the various demands on the system incorporating S/I vs. decadal vs. climate change. This chapter sets the context and outlines common themes.

*General questions to be addressed in Chapter 1:*

- ***Why is this activity important?***
  e.g., $2^{nd}$ Adequacy Report
- What are the demands on the system?
  e.g., S/I vs. decadal vs. climate change
- Why are we observing the ocean?
- Role of ocean in climate
- Why is there a need for an annual assessment?
  - Observing system evolving
  - Capabilities evolve
  - Reanalysis of past record, context
  - Changes in the ocean
    =>ENSO, PDO, NAO, Dipoles, Fisheries, Coastal, SST, Sea ice, Sea level

*Policy-relevant questions to be addressed in Chapter 1:*

- How do the oceans respond to a warming planet?

- How do changes in the oceans affect climate (impacts on society, environment; e.g. ENSO)?
- How can the oceans contribute to improving seasonal atmospheric forecasts?
- How do the oceans affect carbon levels in the atmosphere?
- What are the impacts of the oceanic response to climate change?
- How do changes in the ocean affect fish stocks and fishery management?

*Explanation of the role of the climate system*

An overview of the earth's spheres should be included describing the significance and interconnected nature of each along with cycles, forcing, transports, and feedback mechanisms.

Some of the following information should be included under *The Role of the Oceans:*

- The oceans cover 70% of the Earth's surface.
- The oceans are wet: water vapor from the surface provides source for rainfall and thus latent heat energy to the atmosphere.
- The heat capacity of the atmosphere is equivalent to that of 3.2 m of ocean. The oceans slowly adjust to climate changes and can sequester heat for years.
- The ocean is well mixed to about 20 m depth in summer and over 100 m in winter. An overall average of 90 m would delay climate response by 6 years.
- Total ocean has a mean depth of 3800 m.
- Would add delay of 230 years if rapidly mixed. In reality, the response depends on the rate of ventilation of water through the thermocline (vertical mixing).
- Estimate of delay overall is 10 to 100 years.
- The ocean currents redistribute heat, fresh water, and dissolved chemicals around the globe.
- Absorbs $CO_2$ and other gases and exchanges them with the atmosphere.

## *Chapter 2: State of the Ocean*

The target audience will be decision makers and non-scientists. This chapter will be an annually updated climatology of the ocean, placed in historical context, with discussion of the present uncertainties and with pointers to products of greater detail and climate applications.

Two options for the format of Chapter 2 were presented.

Chapter 2 - Option 1

2.1 Sea level change
  2.1.1 Sea level variability and trends at reference stations
  2.1.2 Global sea level
2.2 Heat and fresh water uptake, transport, and release by the ocean

2.2.1 El Niño and tropical variability
2.2.2 SST and SLP, precipitation, radiation, winds
2.2.3 Surface currents
2.2.4 Ocean heat content and transport
2.2.5 Air-sea exchange of heat, fresh water (E-P), momentum
Land-sea exchange (runoff; E-P on land)
Atmospheric analyses and products
2.2.6 Thermohaline circulation
2.2.7 Sea Ice
2.3 Ocean carbon sources and sinks
2.3.1 Carbon inventory
2.3.2 Air-sea exchange of carbon dioxide
2.4 Biology (future):
2.4.1 Ocean color
2.4.2 Fish stock
2.5 Uncertainties (components vs. synthesis; latter relates to 2.2)

An alternative, more along the lines of CLIVAR, would appear as:

<u>Chapter 2 - Option 2</u>

2.1 Global
2.1.1 Sea level
2.1.2 SST, heat content
2.1.3 Fresh water, salinity
2.1.4 Circulation, THC, gyres, transports
2.1.5 Ocean carbon
2.1.6 Biology and fisheries
2.2 Pacific, including ENSO, PDO
2.3 Atlantic, including THC, NAO, Tropical Atlantic variability
2.4 Indian, Indian Ocean dipole
2.5 Southern Oceans, including sea ice
2.6 Arctic Ocean, including sea ice
2.7 Other Seas, including Mediterranean, marginal seas
2.8 Annual vs. seasonal vs. time series vs. variance; hurricanes, storms (waves), upwelling
2.9 Data access and management

***Chapter 3: State of the Observing System***

The target audience will be NOAA management. System Progress in meeting milestones will be documented by the network managers. Annual statistics and the current status will be given. This section will essentially be a compilation of the annual reports that program PIs typically submit.

Overall System Performance will be evaluated by the expert teams and by the users of ocean observations (the operational forecast centers, research programs, and scientific assessments). Stakeholders not sitting on the expert teams (e.g., ECMWF, BoM, JMA, etc.) will also be invited annually to give formal feedback to the observing system management and recommend improvements needed in the observations for delivery of climate services.

The following is proposed for Chapter 3.

Questions to be addressed by content

- Improvements needed
  - Short articles corresponding to each section of Chapter 2
  - Short articles by open invitation to the forecast centers, research programs, assessments
- How do observations need to be improved to reduce the uncertainties?
- How do observations need to be improved to better initialize models for climate prediction?
- What observations are missing?
- State of data management and access to data
- State of information delivery

Approach and considerations

Compile the annual progress reports, excerpted and edited for program focus.

- Should acknowledge the global obs and NOAA's role
- Links to operational centers/data assimilation (partners)
- Enabled global products and synthesis

Should make comments on satellites and other parts of observing system?

Possible layout and table of contents

3.1 Progress (annual progress reports by network managers)
- 3.1.1 Tide gauge network
- 3.1.2 Drifting buoy array
- 3.1.3 Tropical moored buoy network
- 3.1.4 Ships-of-opportunity network
- 3.1.5 Argo float array
- 3.1.6 Ocean reference stations
- 3.1.7 Carbon inventory and deep ocean survey
- 3.1.8 P$\mathbf{CO_2}$ on ships and moorings

3.1.9 Sea Ice measurements
3.1.10 Dedicated ship support
3.1.11 Data, synthesis, analysis, and re-analysis (GODAE)
3.1.12 Future: ocean color, fish

3.2 System Performance (gaps, overlaps, requirements, recommendations)

3.2.1 Sea level
3.2.2 Heat and fresh water uptake, transport, and release by the ocean
3.2.3 Thermohaline circulation
3.2.4 Ocean carbon sources and sinks
3.2.5 Sea Ice
3.2.6 Data management and access

### *Chapter 4: State of Science*

The target audience will be scientists. The final chapter of the report will contain a bibliography of refereed publications from scientific journals treating the global observation of ocean heat, carbon, fresh water, and sea level change. Each year a selected number of reprints of particularly relevant scientific papers and abstracts will be published with the report. Selection will be by the expert teams.

- Global ocean observing system for climate
- Sea level change
- Heat and fresh water uptake, transport, and release by the ocean
- Thermohaline circulation
- Ocean carbon sources and sinks
- Sea Ice
- Links (heat content, sea level, fluxes etc)

4.1 Selected Abstracts
4.2 Selected reprints from refereed publications
4.3 Bibliography of all science articles and papers

Eventually there should be a commentary on "the state of the science." The author will be chosen in the future.

Participants suggested integration later with atmospheric and terrestrial systems once an appropriate framework has been developed. Links should also be made with updated technology and data assimilation.

**Who should be members of the Expert Teams?**
Likely candidates should be scientists internal and external to NOAA who can:

- Evaluate effectiveness of networks
- Produce adequate deliverables
- Evaluate products, analyses
- Recommend improvements, changed sampling, balance

- Assess impacts of proposed changes

Partnerships are essential and PIs should expand the international dimensions.
A progress report should be included on what is happening internationally.

The CLIVAR Scientific Steering Group might be engaged. OOPC should be engaged from the beginning. Members of these groups should be asked to serve as reviewers.

**General timeline and scale of report**

It was recommended that in Year 1 the initial Annual Report be primarily an OGP document used as a management tool with limited distribution. It can be used to spin off other focused reports. Then, expand and build in subsequent years with annual publication focused at OGP with expansion to NOAA, the United States, and finally global distribution. An end target should be the IPCC.

The end of the report could provide information and data by those not funded by NOAA and could report on the state of science.

**Discussion**

Comments were made including being careful to not expand the Annual Report beyond activities currently being developed and supported by the OCO, particularly in the realm of biology. It was suggested that material on the state of operational efforts be included.

***GROUP 2: SEA LEVEL RISE (Chair: Bruce Douglas)***

Historical *in situ* data are key to reducing uncertainty in historical sea level. Tide gauge record access is less of an issue.

Group 2 presented the primary impacts of sea level rise as:

- erosion of beaches and bluffs
- inundation of low-lying areas
- increased flooding and storm damage
- salt intrusion in aquifers and surface waters
- higher water tables

The global sea level observing system will determine the **volume** & **mass** terms of the sea level budget. Most of the observing elements are either in place or will be put in place in the next few years. The challenge will be to develop synergies to get the most from the system quickly and efficiently.

<u>Volume</u>

Volume Changes are caused by:

- Temperature
- Salinity (Antonov, Levitus and Boyer, 2003)

- Glacial Isostatic Adjustment (GIA)

The Observing System Elements needed for documenting Volume Change are:

- Satellite Altimeters
- Tide Gauges (required for altimeter calibration)
- ARGO (in-situ T & S profiles to mid-depth)
- WOCE-style hydrography (T & S to the ocean bottom)
- GPS measurements of GIA
- Polar motion (angular momentum vector)

<u>Mass</u>

Mass Changes are caused by:

- Antarctic/Greenland ice mass balance
- Mountain glacier wastage
- Sequestration of surface water in reservoirs
- Mining of ground water

The Observing System Elements needed for documenting Mass Changes are:

- ICESAT (Laser altimeter measures topography of polar glaciers)
- GRACE (Gravity Recovery & Climate Experiment measures space/time variability of gravity field)
- Cryosat (Radar altimeter -- will measure topography polar glaciers)
- GPS/DORIS/VLBI (Earth Orientation)

<u>Sea Level Observing System</u>

State of the Observing System:

- 1/3 of GLOSS network doesn't report and may not exist (critical gap in some regions).
- 1/2 of the TOPEX/Poseidon calibration network is not geocentrically located.
- Presently 2 precision altimeters in orbit and the replacement is not funded.
- Data management systems in place, but underfunded.

Metrics:

- Reduction of uncertainty in historical sea level rise
- Reduction of uncertainty in projections of 21st century sea level rise
- Maintenance & enhancement of observing system
- Improved data management and product development

Products:

- Global and regional estimates of sea level change over a range of time scales
- Sea surface heights for assimilation into models
- Altimeter calibration data
- Vertical & horizontal land motions at tide gauge sites
- Science results

**Discussion**

Comments were made that a shorter time scale than the trend is very interesting and there should be more focus on shorter time scale phenomena. Mesoscale and seasonal signals can be retrieved from low-quality altimeter data. The trend is difficult to get...1 to 2.8 mm/yr (according to the IPCC).

### *GROUP 3: AIR-SEA EXCHANGE OF HEAT, WATER, CARBON*
### *(Chair: Bob Weller)*

Group 3 stated that basic fields are key and we must focus on them; reanalysis can always be done to get fluxes. Expert teams should be of two types. One should have a limited lifetime, with focus on particular flux components, basic variable fields and sensors. The second should focus on products and their uncertainties and observing system issues.

Strategy:

- Flux products, especially fields, are synthesized from:
    - In-situ observations
        - Ships (VOS, RV)
        - Buoys (drifting, ocean reference stations, TAO/TRITON, NDBC, etc.)
    - Remote sensing
    - NWP

Present Products:

- Climatologies (COADS, SOC, etc.)
- Satellite-based
- NWP surface fields
- Ocean - ODA
- Blended
- Direct flux

Product Basic Fields:

- SST
- Winds
- Surface radiation
- Air temp
- SLP
- Direct flux measurements - validation of bulk formulas
- Precipitation
- Humidity
- Sea ice - coverage, thickness
- Surface $pCO_2$

- Gas transfer velocity

Expert Teams for Fluxes:

- Tier 1
    - Focus of flux components; liaise with other special teams
    - Across methodologies (in-situ, NWP, satellite)
    - Limited life
    - Error in variables, specific components; sensor issues
    - Pass information to Tier 2 expert team
- Tier 2
    - Focus on products
    - Space/time errors/accuracies in fields, products
    - Observing system issues
    - Dialog with/include users

Performance metrics need to consider:

- How do we revise?
- Who revises?
- Who are we satisfying and how is their feedback taken into account?

Carbon Performance Metrics:

- Complete the Northern Hemisphere ocean observing system to determine $CO_2$ sources and sinks over the US.
    - 3 VOS lines in the Atlantic
    - 1 VOS line in the Pacific
    - FY 06 improve measurements of North Atlantic and North Pacific Basin $CO_2$ fluxes with +/- 0.2 Pg/C per year
    - FY 09 produce seasonal global carbon source and sink maps on 5-degree grid

Heat and Fresh Water Performance Metrics:

- For the tropics and global ocean, implement the surface met observing system to measure the heat and fresh water fluxes
    - FY 05, 4 ocean ocean reference stations
    - Missing VOS and drifters
- Develop realistic flux accuracy goals, TBD

Momentum Performance Metrics:

- For the global ocean, implement the surface met observing system to measure momentum flux
    - Rough estimate: only 10% in place
    - Techniques TBD

Sea Ice Performance Metrics:

- Current Accuracy: 50km spatial resolution, coverage 10%
    - FY 04 initiate installation of coordinated Arctic sea ice thickness

observing system

  - FY 09 initiate validation of satellite based sea ice thickness products with in situ observations

SST Performance Metrics:

- Reduce the error in global measurement of SST
- Estimated error in monthly SST at 500 km resolution in degrees C
  - 2002 1.3°C
  - 2003 1.3°C
  - 2004 1.0°C
  - 2005 0.8°C
  - 2006 0.6°C
  - 2007 0.5°C
  - 2008 0.4°C
  - 2009 0.3°C

**Discussion**

Discussion involved resolution issues involving the scale of temporal and spatial data and error propagation. Greater resolution would be helpful for all prediction efforts.

***GROUP 4: OCEAN CONTENT & TRANSPORT OF HEAT, WATER, CARBON (Chair: Bob Molinari)***

Group 4 participants provided an overview of products available and products needed for the observing system. Each team member provided individual feedback based on his/her area of research.

Products should provide three things:

1. the present state
2. the relationship of the present with the past
3. confidence limits

The group identified a category of "proto products", or products in a developmental stage, that could satisfy all of the above given extra effort and money.

There are few if any products that exist today which include reliable uncertainty estimates. Most systems are still in a research mode with objectives including estimation of means, climatologies and uncertainties. PIs are typically not supported to generate products. Group 4 identified a need to use this annual report to leverage more funds to support development of research products. Performance measures and metrics were not addressed by this group.

The discussion questioned: how "good" is "good enough" to constitute a product? One idea was to use the 10 climate monitoring principles as a guide.

With regard to “Expert” versus “science” teams: science integration is essential for making products with people directly taking measurements involved. Science teams should be considered part of the observing system.

Group 4 felt that Expert Teams should evaluate the products and system status and that they should really be “science” teams intimately involved with the data systems and product generation before oversight “expert” teams are appropriate. Could NOPP help support science teams and product generation?

Products that are now available, or will be by December 2003 include:

- Global heat content - annual mean
- $CO_2$ products
- Global distribution of anthropogenic $CO_2$,
- Atlantic evolution of the observing system today versus 80’s
- Surface currents global maps, regional
- Ice areal extent and motion
- Florida Current transport
- Temperature divergences from drifters
- Mid-depth velocities from Argo floats
- Davis Straits transport retrospective

“Proto Products” include:

- Altimetry maps of heat gain and uncertainty
- Heat transport from XBTs
- $CO_2$ decadal changes by ocean basin (available in 3 year increments)
- PDO index from SST
- Heat/salt content from Argo
- Heat content changes from XBT lines

Products that are missing today were identified as:

- Data for products in the Southern Ocean and Indian Ocean analyses of heat content, subsurface velocity, salinity content, etc.
- Intermediate mode water mass formation rates, property variability and transport, essential for estimates of accumulations of $CO_2$
- Deep water mass formation rates, property variability and transport, essential for estimates of accumulations of $CO_2$
- Ice thickness and fresh water flux from the Arctic
- Western Boundary Currents
- Mixed layer properties: depth, variability, temperature and salinity, etc.
- Time series stations - Papa, Bravo etc.

**Discussion of existing products:**

**Heat Content (Levitus et al.)**

- Heat Content estimates are produced yearly, 6 month, globally on 1° grid.
- Statistical uncertainties necessary to ultimately define heat content by:
  - Steric
  - Dynamical (thermocline)
- Annual cycle cannot at the moment be determined globally, but can along XBT lines.
- Sea level, both the steric component and the eustatic component, can be achieved through Topex and hydro research or modeling and assimilation.

Needs:

- heat content globally
  - annual, seasonal cycle
  - estimates of steric vs dynamic
  - sufficient accuracy to assess anomalies (EOF)
- heat transport globally
- carbon

Uncertainty estimates essential! Must emphasize that we cannot even confidently say what the confidence interval is.

**$CO_2$ anthropogenic snapshots (Feely)**

- First order description of global anthropogenic $CO_2$ content will be available by Dec 2003
- Atlantic changes on decadal time scale basin wide
- Changes in Pacific along select lines from the 70, 80-90's
- Basin synthesis studies take 3 years each (Atlantic done)
- Want interannual variability, decadal subsurface changes
- Have surface variability (order 6 month changes).
- Research results: $CO_2$ flux along 24°N in Atlantic (Macdonald et al)

Needs/advancements:

- Technical advances - moorings and floats
- Increased obs in Southern Ocean
- Expansion of VOS network
- Increased international coordination

**XBTs (Garzoli)**

Heat transport estimates from XBTs
Decadal changes from XBTs
Confidence intervals

Needs:

- Deeper XBTs

- Salinity
- Active research areas - not great research “products” until uncertainties are well understood. Better to focus on improving our estimates than making a new number.
- Would need to centralize the activity, but it is important now to keep estimates local where the research expertise resides.
- Mass transport. From satellites.

**Surface Currents (Niiler)**

- Global map of surface currents at limited resolution 2x6 are available from 1978 to today. They include estimates of v’del t divergence.
- Tropical Pacific - T flux convergence (mean). V variance fields.
- Regional pictures of velocity fields over the past 10 yrs 1/2 degree resolution (e.g. California Current)
- Plus uncertainties

Needs:

- satellite data
- 1 page Tropical Pacific, several pages for global product

Customers:

- modelers

**Hydrographic Surveys (Johnson)**

Repeat hydro lines 1.5-2 years could go into annual report occasionally.

- deep property field changes
- heat and fresh water transport

Tropical Pacific: ADCP long term means (should be a product development effort, with additional funding needed)

Argos sections, individual profiles, maps of locations, etc., could be included.

**Proto Products (Roemmich)**

- Altimetry maps of annual mean heat gain (unknown uncertainty)
- Performance measure - float density
- Heat transport in N. Pacific/S. Pacific, S. Indian (from HD XBT)
- Future Argo: large scale transports of heat/fresh water. Also fresh water “storage”

**Velocity Fields and Heat Content (Owens)**

Velocity fields mid-depth basin scale (select basins) have been done (each basin by a different group). S. Pacific, Indian Ocean, Lab Sea (using Argo). Heat content Northern N. Atlantic (with salt and heat content).

**Sea Ice and Arctic Fluxes (Rhines)**

- SEARCH - NW Passage, fresh water fluxes from Arctic. Product?
- Hydrographic program based on SeaGliders
- Retrospective transport analyses through Arctic Straits

- Upward looking sonars to look at ice draft

Need: Ice thickness
Need: Fresh water flux out of Arctic

**Arctic Ice motion, area and extent from buoys and satellites (Ignatius)**
Need: We have a less clear picture of the mass and volume of sea ice, which is more important (i.e., determines the fresh water flux from the Arctic). To address this question we are deploying buoys, which measure the thickness of sea ice (mass balance) and upward looking sonars.

**Heat (Molinari)**
- Heat content time series along XBT lines
- Gulf Stream transport across XBT lines

**Heat Transport (Baringer)**
- Heat transport estimates from XBTs (a research product)
- Florida current mass transport since 1982, heat transport quarterly since 1998
- Deep Western Boundary Current property time series since early 1980's
- Repeat hydrography estimates should also include mass - meridional overturning circulation as well as heat and fresh water.

There is a great deal of concern about the uncertainty estimates that will have to be assigned. Uncertainties are large and the modeling community needs covariance fields. There is so little data that it is challenging to compute means at the present. There need to be realistic expectations of the feasibility of the research.

Mike Johnson ended the day's session by stating that there is a real need for system engineering in addition to the science that is usually discussed at meetings. To build the observing system, we have to deal with the engineering component. He expressed thanks to all for working through the challenging breakout groups and providing a great start to guiding the future engineering of the observing system.

A poster session and reception was held in the evening.

**Session 4 – Program and Budget (Chair: Mike Johnson)**
Thursday morning, 15 May

Mary Glackin, AA for Program Planning and Integration (PPI), started the morning session by stating that the effort to improve the integrated observing system is important to NOAA and an example of a new way of doing business across NOAA and within the US. She stated that you cannot build only climate…you also have to support other demands of NOAA services and work with other communities and agencies. She stated that Vice Admiral Lautenbacher has traveled globally to build support for a global observing system.  After the Earth Observation Summit on 31 July the hard work begins with those having to do the implementation plan and then make it happen.  It is important to set priorities.  She stated that climate observing is fairly well organized and that we have a good chance, if we keep our eyes open, to possibly continue to build more quickly than has been done in the past.  A brief Q & A session followed with questions mainly addressing future observations and decisions.

Mike Johnson thanked Mary for her presentation and then recapped the state of the Climate Observing Program and program planning.  Discussion followed and Mike thanked everyone for attending and participating.  He expressed the need for everyone's future input to continue moving forward.

After a short break the COSC met in executive session to discuss issues of importance to the Office of Climate Observation, especially development of the Annual Report.

***Conclusions***

The Annual Report will present climate products in understandable ways to decision makers, the science community, and the public.  At the same time this reporting framework will establish a formal mechanism for implementing a "user-driven" observing system for reporting on the system's performance in meeting the requirements of the operational forecast centers, international research programs, and major scientific assessments.  Stakeholders will be invited to provide formal recommendations for system improvement and evolution as part of the annual report process.

**Appendix A: Agenda and Participants' Presentations**

To view a speaker's PowerPoint presentation, click on their name in the agenda below.

**AGENDA**

**Climate Observing System Council**
**and**
**Climate Observation Program Workshop**
**Focus on the Ocean**
**13-15 May 2003**
**Holiday Inn**
**Silver Spring, MD**

Workshop Objectives:

1. Institute an Annual Program Review.
2. Design a framework for regular reports on the state of the ocean and the adequacy of the observing system for climate.
3. Design a framework for implementing expert teams to continually evaluate the skill and effectiveness of ocean products and of the observing system.

## Tuesday, 13 May 2003

| | | | |
|---|---|---|---|
| 0800 | Coffee | $4^{th}$ Floor outside Kennedy Ballroom | |
| | Poster set-up | $4^{th}$ Floor Lincoln Ballroom | |
| | COSC executive session | $4^{th}$ Floor Kennedy Ballroom | |
| 0830 | Workshop Welcome (5 min) | $4^{th}$ Floor Kennedy Ballroom | M. Johnson |
| 0835 | The Foundations of the Climate Observation Program (15 min) | | K. Mooney |
| 0850 | The Future of the NOAA Climate Program – Implications for Observing Systems (30 min) | | M. Glackin<br>D. Goodrich |
| 0920 | Workshop Objectives (20 min) | | M. Johnson |
| **0940** | **Session 1 – Partnerships and Requirements** | Chair: | P. Niiler |
| 0940 | GCOS Second Adequacy Report for the UNFCCC (30 min) | | E. Harrison |
| 1010 | Climate Change Science Program (20 min) | | C. Koblinsky |
| 1030 | Break (20 min) | | |

| | | |
|---|---|---|
| 1050 | Planning for an Integrated Ocean Observing System (20 min) | E. Lindstrom |
| 1110 | NOAA Observing System Architecture (20 min) | M. Neyland |
| 1130 | Policy-relevant Questions (20 min) | S. Wilson |
| 1150 | The Ocean Observatory Initiative, NSF (20 min) | B. Weller |
| 1210 | South Atlantic Climate Observing System Workshop (20 min) | S. Garzoli |
| 1230 | Lunch (60 min) | |
| 1330 | Indian Ocean Observing System for Climate (20 min) | M. McPhaden |
| 1350 | High-Resolution Marine Meteorology Workshop (20 min) | S. Smith |
| 1410 | Seasonal Forecasting Priorities for the Observing System (20 min) | Y. Xue |
| 1430 | Decadal Forecasting Priorities for the Observing System (20 min) | T. Delworth |
| 1450 | Break (20 min) | |
| **1510** | **Session 2 – Annual Report** Chair: | D. Stanitski |
| 1510 | Annual report as a system organizing framework (20 min) | M. Johnson |
| 1530 | State of the Climate Reports (20 min) | T. Karl |
| 1550 | Discussion – structure of an Annual Report (40 min) | |
| *1630* | *Poster Session* | |

1730-1930 **Poster Session Continued -- Reception in the Poster Room**

## Wednesday 14 May 2003

| | | |
|---|---|---|
| 0800 | Coffee, **Poster Session Continued** | |
| **0830** | **Session 3 – Expert Teams and the Annual Report** Chair: | E. Sarachik |
| 0830 | Observation System Overview, Assessment & Oversight (20 min) | T. Karl |
| 0850 | ODASI Consortium (20 min) | M. Rienecker |
| 0910 | Expert Teams and the Annual Report (20 min) | M. Johnson |

| | | |
|---|---|---|
| 0930 | Plenary Discussion – Annual Report Structure (40 min) | K. Trenberth |
| 1010 | Break (20 min) | |
| 1030 | Break-Out Groups to design an annual report (3.5 hours) | |
| | Group 1: Report structure | K. Trenberth |
| | Group 2: Sea Level | B. Douglas |
| | Group 3: Air-sea exchange of heat, water, carbon | B. Weller |
| | Group 4: Ocean content & transport of heat, water, carbon | B. Molinari |
| 1230 | Lunch (60 min) | |
| 1330 | Break-Out Groups continue | |
| 1500 | Break (20 min) | |
| 1520 | Plenary – Group reports (each 20 min) | |
| 1640 | Discussion (50 min) | |
| 1730-1930 | **Poster Session Continued -- Reception in the Poster Room** | |

## Thursday 15 May 2003

| | | |
|---|---|---|
| 0800 | Coffee | |
| **0830** | **Session 4: Program and Budget** | Chair: M. Johnson |
| 0830 | The NOAA Climate Program (30 min) | M. Glackin |
| 0900 | Climate Observation Program and Budget (60 min) | M. Johnson |
| 1000 | Break (30 min) | |
| 1030 | Workshop adjourn, COSC executive session | |
| 1230 | COSC adjourn | |

**Appendix B: Participants' Posters**

To see a poster listed below, click on the italicized title of the poster.

Baringer, M., E. Johns, R. Smith, S. Garzoli, C. Meinen, W. Johns, L. Beal, J. Marotzke, S. Cunningham, and H. Bryden, *Western Boundary Current Time Series*.

Baringer, M., R. Molinari, G. Goni, and S. Garzoli, *Sustained XBT Observations for North Atlantic Climate Variability*.

Cook, S., Y-H.C. Daneshzadeh, *Collection and Data Management of Thermosalinograph Observations*.

Daneshzadeh, Y-H. C., *Upper Ocean Temperature Delayed Mode Quality Control (QC).*

Garzoli, S.L., P. Niiler, R. Lumpkin, and M. Pazos, *Mixed-Layer Heat Transport in the Tropical Atlantic*.

McPhaden, M.J., *The Tropical Atmosphere Ocean (TAO) Project*.

Meinen, C.S., S.L. Garzoli, W.E. Johns, and M.O. Baringer, *Transport of the Antilles Current and the Deep Western Boundary Current off Abaco, Bahamas: Results from Inverted Echo Sounders, Bottom Pressure Gauges, and Current Meters*.

Molinari, R.L., *The Elements of A Future Observing System in the Subtropical Atlantic*.

Molinari, R.L., *The GOOS Center at AOML – An Overview for 2002*.

Molinari, R.L., R. Lusic, S. Garzoli, G. Goni and M. Baringer, *Benchmarks for Atlantic Ocean Circulation*.

Pazos, M.C. and J. Redman, Drifter Data Assembly Center (DAC): A Summary of Data Products Available on the Web.

Pazos, M.C., C. Engler, and J. Redman, *Global Drifter Center (GDC) / Drifter Data Assembly Center (DAC).*

Plueddemann, A., *In-Situ Meteorology and Air-Sea Fluxes in the Northwest Tropical Atlantic*.

Reynolds, R.W., H-M. Zhang, and T.M. Smith, *Sea Surface Temperature (SST) Buoy Need Network for Climate.*

Rigor, I.G., J. Richter-Menge, and J. Morison, *Study of Environmental Arctic Change (SEARCH): An Arctic Ocean Observing System: Ice and Ocean Components*.

Roemmich, D., R. Davis, J. Gould, G. Johnson, A. Wong, R. Molinari, S. Garzoli , W.B. Owens, S. Riser, *The Argo Project: Observing the Global Ocean in Real-Time*.

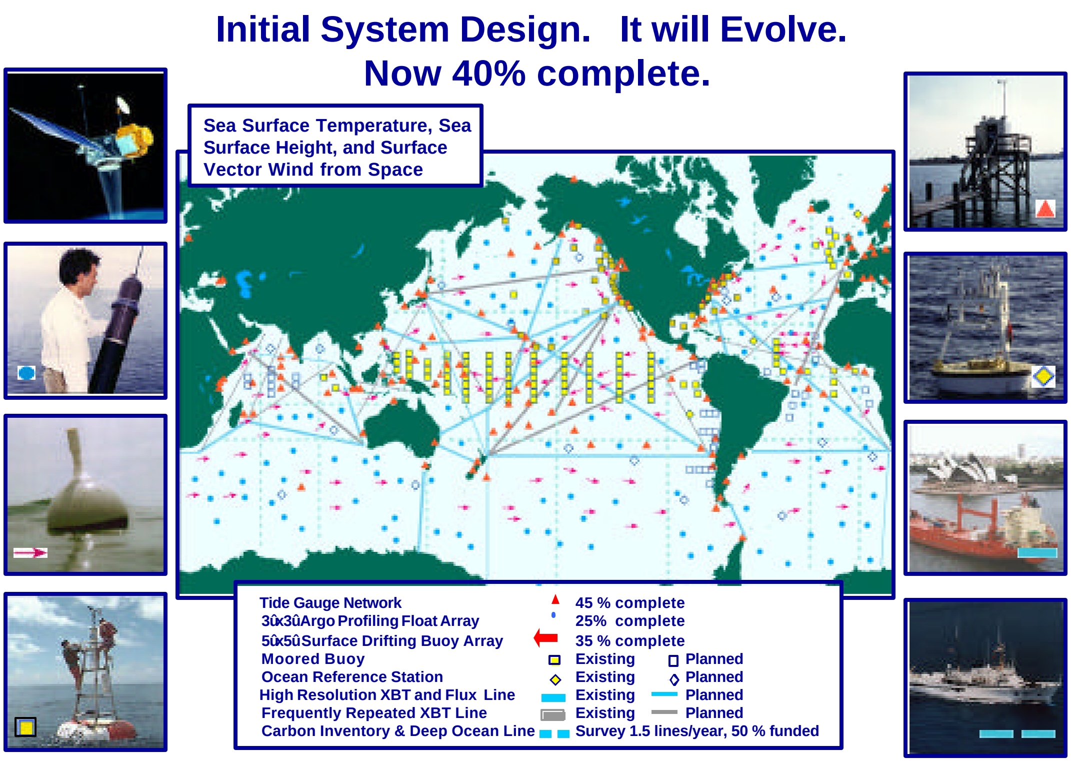
Wanninkhof, R., R. Feely, C. Sabine, Bullister, G. Johnson, and M. Baringer; Joint Institute Partners: J-Z. Zhang, C. Mordy, *Objectives of the $CO_2$ /CLIVAR Repeat Hydrography Program*.

Wilburn, A-M., *XBT Operations*.

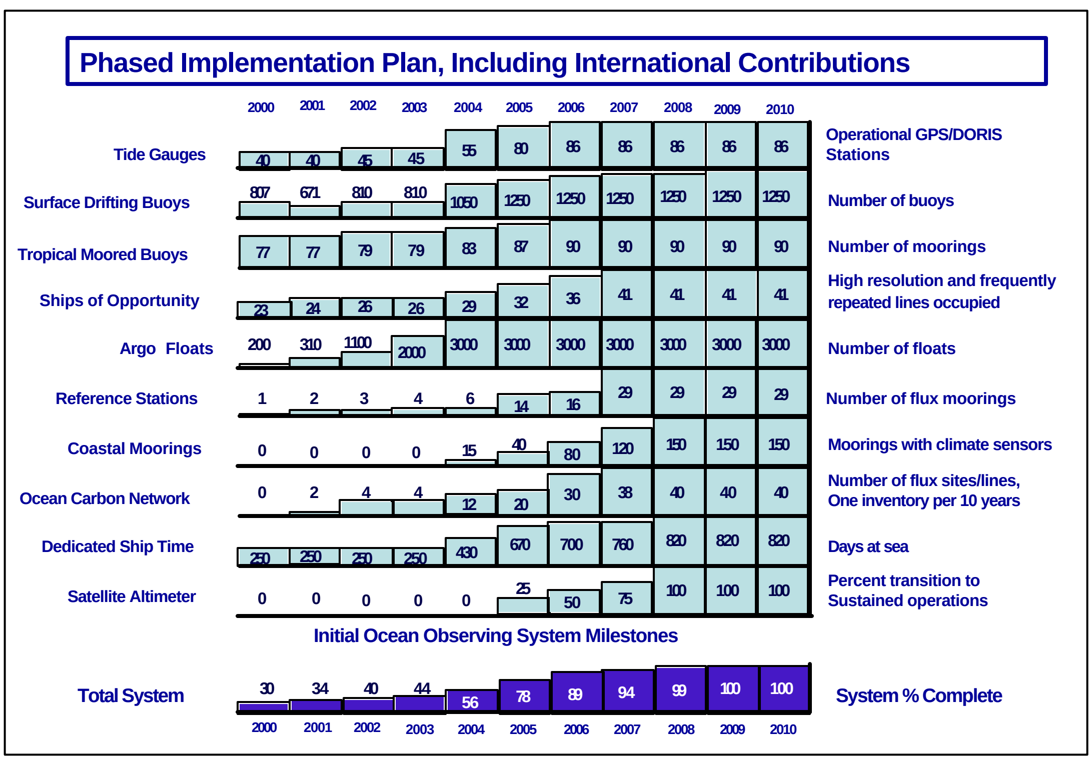
Zervas, C.E., *Sea Levels Online: A NOAA Website For Sea Level Trends And Variability*.

## Appendix C: Graphics

Appendix C.1 Global Ocean Observing System for Climate and Marine Services




Appendix C.2 Phased Implementation Plan



## Appendix D: Workshop Details

### Appendix D.1: Invitation to Participate

Dear Climate Observationalists:

You are invited to participate in a Climate Observation Program Workshop, 13-15 May 2003, to help chart the future of the Program. The workshop is tentatively slated to take place in Silver Spring. Please see the attached introductory information.

Regards, Mike

Climate Observation Program Workshop
Focus on the ocean
13-15 May 2003
Silver Spring, MD

Introductory Information

NOAA is establishing a new project office to advance the climate observing system. The details are still in the developmental stage but here are some of the main ideas:

- Mission statement – Build and sustain a global climate observing system that will respond to the long-term observational requirements of the operational forecast centers, international research programs, and major scientific assessments.
- Dual reporting to the NOAA Climate Program Office (operations) and the Office of Global Programs (research).
- "Pilot project office" doors open May 2003 at OGP. Office may shift to a different location if/when operations dictate.
- Initial focus – monitor, evaluate, evolve the ocean networks. Add the atmospheric networks asap.
- Climate Observation Program to provide many of the initial core elements.
- Initiate product delivery as the organizing framework:
    - Mission requirement -- Routine delivery of an annual report on the state of the ocean, progressing to an annual report on the state of the climate by 2008.
    - Address CCSP Question: "What is the current state of the climate, how does it compare with the past, and how can observations be improved to better initialize and validate models for prediction or long term projection?"

The workshop will be concurrent with the next meeting of the Climate Observing System Council and the COSC will be asked to use this workshop for a fresh overview of the Program as we move into this new phase of growth. It's important for us all to talk about strategies and tactics for the future success of the Program.

Several folks on the address list have not been directly involved with the Climate Observation Program in the past but you are key players in the observation game and your help in shaping the Program would be much appreciated. I hope that you will be able to contribute your expertise to this workshop.

The proposed objectives are:

- Institute an "annual program review" – i.e., an annual Project Managers (PI) meeting.
- Establish the program's plan of action -- objectives, performance measures, milestones (many of you have already provided input to a draft program plan – a second draft will be sent out to workshop participants for review and finalizing at the workshop).
- Initiate "expert teams" (see the draft Concept write-up below).

Because there are about 40 funded projects in the existing Program we need an efficient way to communicate about the ongoing activities. I am asking each PI to put together an AGU/AMS style poster and associated Power Point slides for their project. At this time we are not planning to schedule individual project presentations during the workshop. Instead the Power Points will be made available prior to the workshop and there will be time for all to view the posters during a poster session at the meeting. In case you cannot make the trip to Silver Spring your project will still be described as part of the overall program.

I know that you were not anticipating this workshop in your travel budgets but hope you can re-program your existing funds to accommodate this meeting. I believe that this workshop will be an important milestone in building the sustained ocean observing system for climate.

Your ideas/comments regarding the scope for the workshop are very welcome as the planning progresses over the next couple of months. If you notice in the address list that I have missed an important participant please forward this to him/her and let me know so I can add to the mailing list. Thanks.

Draft Concept -- Annual Report on the Ocean's Role in Climate

The organizing framework to bring the multiple elements of the composite ocean observing system together will be the routine delivery of an Annual Report on the Ocean's Role in Climate. The National Climate Change Science Program strategic plan has identified the critical need for regular reports documenting the present state of the climate system components. NOAA's project office for climate observation will undertake this reporting for the ocean component. The theme of the report will be CCSP question #3.2 - "What is the current state of the climate, how does it compare with the past, and how can observations be improved to better initialize models for prediction?"

This will require the establishment of "expert teams" of scientists to continually evaluate the skill and limitations of climate products and the effectiveness of the networks in providing the needed data. Program PIs will be invited to propose to participate in the expert teams as will other experts that provide/use the data and products. The expert teams will evaluate analysis/synthesis products, recommend product improvements, recommend where additional sampling is needed or redundancies are not needed, recommend better utilization of existing and new in situ and satellite data, and assess the impacts of proposed changes to the system.
The annual report will present climate products in understandable ways to decision makers, the science community, and the public. At the same time this reporting framework will establish a formal mechanism for implementing a "user-driven" observing system and for reporting on the system's performance in meeting the requirements of the operational forecast centers, international research programs, and major scientific assessments. Stakeholders will be invited to provide formal recommendations for system improvement and evolution as part of the annual report process.

It is proposed that the annual report contain three chapters:

1) The first chapter will document the State of the Ocean. The target audience will be decision makers and non-scientists. This chapter will be written by the expert teams and will be an annually updated climatology of the ocean, placed in historical context, with discussion of the present uncertainties and with pointers to products of greater detail and climate applications.

2) The second chapter will document the State of the Observing System. The target audience will be NOAA management. This chapter will have two sections:

a) System Progress in meeting milestones will be documented by the network managers. Annual statistics and status will be given. This section will be essentially a compilation of the annual reports that program PIs are used to writing.
b) Overall System Performance will be evaluated by the expert teams and by the users of ocean observations (the operational forecast centers, research programs, and scientific assessments). Stakeholders not sitting on the expert teams (e.g., ECMWF, BoM, JMA, etc.) will also be invited annually to give formal feedback to the observing system management and recommend improvements needed in the observations for delivery of climate services.

3) Chapter three will recap the State of the Science. The target audience will be scientists. The final chapter of the report will contain a bibliography of refereed publications from scientific journals treating the global observation of ocean heat, carbon, fresh water, and sea level change. Each year a selected number of reprints of particularly relevant scientific papers and abstracts will be published with the report. Selection will be by the expert teams.

Preliminary Outline
Annual Report on the Ocean's Role in Climate
A Report of the NOAA Climate Observation Program—Ocean Component

1. The State of the Ocean

1.1 Sea level change

1.1.1 Sea level variability and trends at reference stations
1.1.2 Global sea level

1.2 Heat and fresh water uptake, transport, and release by the ocean

1.2.1 El Nino and tropical variability
1.2.2 SST and SLP
1.2.3 Surface currents
1.2.4 Ocean heat content and transport
1.2.5 Air-sea exchange of heat, fresh water, momentum
1.2.6 Thermohaline circulation
1.2.7 Sea Ice

1.3 Ocean carbon sources and sinks

1.3.1 Carbon inventory
1.3.2 Air-sea exchange of carbon dioxide

2. The State of the Observing System

2.1 Progress (annual progress reports by the network managers)

2.1.1 Tide gauge network
2.1.2 Drifting buoy array
2.1.3 Tropical moored buoy network
2.1.4 Ships-of-opportunity network
2.1.5 Argo float array
2.1.6 Ocean reference stations
2.1.7 Carbon inventory and deep ocean survey
2.1.8 PCO2 on ships and moorings
2.1.9 Sea Ice measurements
2.1.10 Dedicated ship support
2.1.11 Data, synthesis, analysis, and re-analysis (GODAE)

2.2 System Performance (gaps, overlaps, requirements, recommendations)

2.2.1 Sea level
2.2.2 Heat and fresh water uptake, transport, and release by the ocean

2.2.3 Thermohaline circulation
2.2.4 Ocean carbon sources and sinks
2.2.5 Sea Ice

3. The State of the Science

o Global ocean observing system for climate
o Sea level change
o Heat and fresh water uptake, transport, and release by the ocean
o Thermohaline circulation
o Ocean carbon sources and sinks
o Sea Ice

3.1 Selected Abstracts
3.2 Selected reprints from refereed publications
3.3 Bibliography of all science articles and papers

**Appendix D.2 List of Participants**

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**Appendix D.3: Charge to Working Groups**

## Abbreviated DRAFT Charge to Breakout Groups

Group 1: Report Structure

- Recommend a report structure
    - See several models & strawmen
    - Draft a table of contents
- Recommend an expert team framework
- Recommend a report oversight and review mechanism
    - See draft terms of reference

Groups 2, 3, and 4: Sea Level, Air-Sea Exchange, and Ocean Content and Transport

- Recommend products needed
    - Suggested starting points in packet
        - GCOS Adequacy Report -- discussion of goals and products
        - Draft CCSP Strategic Plan -- state and forcing/feedback variables
        - Ocean.US Workshop Proceedings -- priority variables
- Recommend an expert team framework
- Recommend metrics that will demonstrate progress

## Expanded DRAFT Charge to Breakout Groups

### Group 1: Structure of an Annual Report

1. What should be the title?

2. How should the report be structured? Some models:

- The initial draft outline based on the Program Plan
    - Draft outline pasted below
- The NCDC annual Climate Assessment
    - (http://www.ncdc.noaa.gov/oa/climate/research/2001/ann/annsum.pdf)
        - Introduction
        - Global climate
        - Trace gases and radiative forcing
        - The Tropics
        - The Poles
        - Regional climate
        - Seasonal summaries
- Policy-relevant questions

- How do the oceans respond to a warming planet?
- How can the oceans contribute to improving seasonal atmospheric forecasts?
- How do the oceans affect carbon levels in the atmosphere?
- What are the impacts of the oceanic response to climate change?

- Another Straw Man
  - Executive Summary – highlights
  - State of system-wide coordination
  - State of data management and information delivery
  - Effectiveness in supporting climate forecasting
  - Sea Level Change
  - Ocean carbon sources and sinks
  - Air-sea exchange of heat and water
  - Ocean content and transport of heat and fresh water
- Another Straw Man
  - Chapter 1: Introduction (general motivation)
  - Chapter 2: The ocean's role in the climate system (science review and update with particular emphasis on implications for the observing system)
  - Chapter 3: The state of the ocean (assessment/synthesis and attribution: what has been going on during the last decade, projections for the future?, applications?)
  - Chapter 4: The state of the ocean observing system (past, present and future of the observing system that was used to produce the results for chapter 3, most likely network specific, and spell out future needs)
- Others

3. Draft a report outline (Table of Contents).

4. What Expert Teams are needed for system evaluation?

"Subtask 2 - Evaluation: Expert teams of scientists both internal and external to NOAA will be established to continually evaluate the effectiveness of the networks in meeting the performance measures and the adequacy of the deliverables in meeting the system objectives. The expert teams will evaluate analysis/synthesis products, recommend product improvements, recommend where additional sampling is needed or redundancies are not needed, recommend better utilization of existing and new *in situ* and satellite data, and assess the impacts of proposed changes to the system."

- Straw man framework:
  - Seasonal forecasting
  - Decadal forecasting
  - Sea level change
  - Carbon sources and sinks
  - Air-sea exchange of heat and water
  - Ocean heat content and transport, and thermohaline circulation
  - SST

- Sea Ice

5. Recommend an oversight and review mechanism -- see the straw man Terms of Reference pasted below the draft outline.

Initial DRAFT Outline:

Preliminary Outline
Annual Report on the Ocean's Role in Climate

## A Report of the NOAA Climate Observation Program—Ocean Component

1. The State of the Ocean (target audience – decision makers, non-scientists)
    - 1.1 Sea level change
        - 1.1.1 Sea level variability and trends at reference stations
        - 1.1.2 Global sea level
    - 1.2 Heat and fresh water uptake, transport, and release by the ocean
        - 1.2.1 El Nino and tropical variability
        - 1.2.2 SST and SLP
        - 1.2.3 Surface currents
        - 1.2.4 Ocean heat content and transport
        - 1.2.5 Air-sea exchange of heat, fresh water, momentum
        - 1.2.6 Thermohaline circulation
        - 1.2.7 Sea Ice
    - 1.3 Ocean carbon sources and sinks
        - 1.3.1 Carbon inventory
        - 1.3.2 Air-sea exchange of carbon dioxide

2. The State of the Observing System (target audience – management)
    - 2.1 Progress (annual progress reports by the network managers)
        - 2.1.1 Tide gauge network
        - 2.1.2 Drifting buoy array
        - 2.1.3 Tropical moored buoy network
        - 2.1.4 Ships-of-opportunity network
        - 2.1.5 Argo float array
        - 2.1.6 Ocean reference stations
        - 2.1.7 Carbon inventory and deep ocean survey
        - 2.1.8 PCO2 on ships and moorings
        - 2.1.9 Sea Ice measurements
        - 2.1.10 Dedicated ship support
        - 2.1.11 Data, synthesis, analysis, and re-analysis (GODAE)
    - 2.2 System Performance (gaps, overlaps, requirements, recommendations)
        - 2.2.1 Sea level
        - 2.2.2 Heat and fresh water uptake, transport, and release by the ocean
        - 2.2.3 Thermohaline circulation
        - 2.2.4 Ocean carbon sources and sinks
        - 2.2.5 Sea Ice

3. The State of the Science (target audience – scientists)
    - Global ocean observing system for climate
    - Sea level change
    - Heat and fresh water uptake, transport, and release by the ocean
    - Thermohaline circulation
    - Ocean carbon sources and sinks
    - Sea Ice

  3.1 Selected Abstracts
  3.2 Selected reprints from refereed publications
  3.3 Bibliography of all science articles and papers

## Terms of Reference

Annual report on the state of the ocean
and the adequacy of the observing system for climate

### Introduction

The National Climate Change Science Program (CCSP) strategic plan has identified the critical need for regular reports documenting the present state of the climate system components. NOAA's Project Office for Climate Observation (OCO) will contribute to the national effort to institutionalize this reporting by developing an annual report on the state of the ocean and the adequacy of the observing system for climate. The theme of the report will be the CCSP overarching question: "What is the current state of the climate, how does it compare with the past, and how can observations be improved to understand and interpret trends, and better initialize, test and improve models for prediction or long-term projection?"

### Coordination

The annual report will identify, make use of to the extent possible, and complement related activities in the U.S. and/or internationally. These terms of reference are intended to guide NOAA's contributions initially, but are established with a view toward future integration with the Councils, Boards, and Teams of the CCSP as that nascent interagency management structure develops. A process for engaging international stakeholder groups and establishing ongoing dialogue with them must also be developed. The report should be closely coordinated with any development of educational tools to improve public understanding of the oceans' role in climate that may be supported in parallel through the CCSP.

### Scope and Coverage

The annual report will present climate products in understandable ways to decision makers, the science community, and the public. At the same time this reporting framework will establish a formal mechanism for reporting on the system's performance in meeting the requirements of the operational forecast centers, international research programs, and major scientific assessments. Stakeholders will be invited to provide formal recommendations for system improvement and evolution as part of the annual report process.

It is understood that the report will be a policy-neutral and unbiased product of the broad scientific community. Information for decision makers and other stakeholders will be policy- and/or decision-relevant and developed through partnerships involving scientists, managers, and selected end users. Policy- and decision-relevant aspects of the report will focus on a few key issues for which information needs can be identified, and where useful information on high priority issues can be produced.

The annual report will have three objectives:

1) Explain the State of the Ocean to decision makers and non-scientists. This focus will provide an annually updated climatology of the ocean, placed in historical context, with discussion of the present uncertainties and with pointers to products of greater detail and climate applications.

2) Document the State of the Observing System. The target audience will be NOAA management. This focus will have two sections:

a) Observing System Progress in meeting milestones will be documented by the network managers. Annual statistics and status will be given.

b) Overall System Performance will be evaluated by the users of ocean observations (the operational forecast centers, international research programs, and major scientific assessments). Stakeholders will be invited annually to give formal feedback to the observing system management and recommend improvements needed in the observations for delivery of climate services.

3) Address the State of the Science. The target audience will be scientists. The final focus will provide a bibliography of refereed publications from scientific journals treating the global observation of ocean heat, carbon, fresh water, and sea level change. Each year a selected number of reviewed articles and/or reprints of particularly relevant scientific papers and abstracts will be included in the report.

**Leadership and Authorship**

**Writing:** The responsibility for content of the annual report will be assigned to several Expert Teams. The Expert Teams will secure input and participation from a broad and diverse cross section of scientists, managers, and stakeholders sufficient to ensure the breadth, depth, balance and independence of views requisite for the highest quality possible in the finished product. The Expert Teams will identify and secure the services of lead and contributing authors as appropriate. Opportunities for offering information will be broadly disseminated in appropriate scientific, operational, and other public venues.  The Expert Teams will also ensure that relevant scientific bodies are informed of the intent and progress of the report and will seek to harmonize their efforts with ongoing relevant work of the CCSP scientific bodies.

**Production:** The responsibility for producing the report will be assigned to a group of experts hereby termed the Production Team.  Members will include the Chairperson from each Expert Team, the Chairperson of the Climate Observing System Council (COSC), and the OCO Associate Program Manager.  They will provide leadership in planning, developing, coordinating, integrating and publishing the report.  The Production Team will take steps to determine the range of aspects that will be covered in the report and be responsible for coordinating and integrating all inputs to ensure the report is well integrated, balanced, responsive and credible.   Distribution of the final publication will be arranged for by the Production Team in consultation with the Executive Committee.

**Oversight and Review:** An Executive Committee, to be composed of representatives of the COSC, the Director of the Office of Global Programs, the Director of the NOAA Climate Program Office, the Chairperson of the CCSP WGOM, and additional persons as needed to ensure critical expertise is represented, will oversee the work of the Production Team.  The Executive Committee will provide only top-level guidance.  They will focus on general report direction and schedule and helping to ensure that available data, analyses, and information are brought to the attention of the Production Team and in facilitating liaison with stakeholder groups.  It is envisioned that individual chapters and/or the full document(s) will be reviewed prior to final publication.  The Executive Committee will be responsible for arranging for external review(s).

**Schedule:**

The first report should be completed by 1 May 2004.  A draft, summarizing content and development and production processes, should be presented to the Executive Committee by 1 September 2003.  Invitation to stakeholders to provide feedback on observing system effectiveness should be issued by 1 October 2003.  The draft manuscript should be submitted to the Executive Committee by 1 February 2004.  The scientific review should be completed by 15 March 2004.  The Production Team should assure that the review comments are reflected in the final report.  The completed manuscript should be submitted by 15 April and be published by the OCO.

## Group 2:  Sea Level

1. What products are presently available that could, with minor editing, contribute to a first (2003) annual report on the state of the ocean?  Each product needs to describe:

- The present state
- How it compares with the past
- The confidence/uncertainty in this product

2. What products are presently available that could contribute with marginal improvement? Could these be available by December 2003?

3. What products are missing today that need to be developed to give a complete picture of the ocean's contribution to the state of the climate system?

4. What Expert Teams are needed for evaluation of this part of the system?

> "Subtask 2 - Evaluation: Expert teams of scientists both internal and external to NOAA will be established to continually evaluate the effectiveness of the networks in meeting the performance measures and the adequacy of the deliverables in meeting the system objectives. The expert teams will evaluate analysis/synthesis products, recommend product improvements, recommend where additional sampling is needed or redundancies are not needed, recommend better utilization of existing and new *in situ* and satellite data, and assess the impacts of proposed changes to the system."

- Straw man framework:
    - Seasonal forecasting
    - Decadal forecasting
    - Sea level change
    - Carbon sources and sinks
    - Air-sea exchange of heat and water
    - Ocean heat content and transport, and thermohaline circulation
    - SST
    - Sea Ice

5. What Performance Measures and Metrics are needed to evaluate progress in building the system? The Office of Program Analysis and Evaluation uses this simple litmus test: "So what? Who cares?" In other words, why should the taxpayers buy a multi-million dollar observing system? If they do, how will they know that it is paying off? What should an annual report be striving to deliver?

The best metrics are ones that can be graphed so that progress toward targets can be tracked visually. Examples:

Performance Measure 1: Reduce the uncertainty in projections of sea level rise during the 21st century.

Metric: Range between estimates of sea level rise (centimeters):

| 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|
| 80 cm | 80 cm | 70 cm | 60 cm | 50 cm | 40 cm | 30 cm | 25 cm |

Performance Measure 2: Reduce the uncertainty in estimates of the increase in carbon inventory in the global ocean.

Metric: Uncertainty in estimates of anthropogenic change per decade (Gigatons):

| 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|
| 10 Gt | 10 Gt | 10 Gt | 8 Gt | 8 Gt | 7 Gt | 6 Gt | 4 Gt |

Performance Measure 3: Reduce the error in global measurement of sea surface temperature.

Metric: Estimated error in monthly analysis of sea surface temperature at 500 kilometer resolution (degrees Celsius):

| 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|
| 1.3 C | 1.3 C | 1.0 C | 0.8 C | 0.6 C | 0.5 C | 0.4 C | 0.3 C |

Below are pasted the metrics presently in the Program Plan. Can these be improved to be more consistent with the style above and be more reflective of where we are trying to go with an annual report on the ocean's role in climate?

**5.1 Document long-term trends in sea level change.**

Performance Measure 4: Complete the installation of real-time, remote reporting tide gauges and co-located permanent GPS receivers at the international GLOSS subset of 62 stations for Long Term Trends and subset of 30 stations for altimeter drift calibration.

Performance Measure 5: Establish the permanent infrastructure necessary to process and analyze the tide gauge and GPS data and deliver routine annual sea level change reports.

Metrics:

- By FY 05, for 16 climate reference stations in the United States, routinely deliver an annual report of the variations in relative annual mean sea level for the entire length of the instrumental record.
- By FY 06, for 16 climate reference stations in the United States, routinely deliver an annual report of the monthly mean sea level trend for the past 100 years with 95% confidence interval.
- By FY 07, for 62 climate reference stations worldwide, routinely deliver an annual report of the variations in relative annual mean sea level for the entire length of the instrumental record.
- By FY 08, for 62 climate reference stations worldwide, routinely deliver an annual report of the monthly mean sea level trend for the past 100 years with 95% confidence interval.
- By FY 08, routinely deliver an annual report of global absolute sea level change to an accuracy of 1 mm per year.

## Group 3: Air-sea exchange of heat, water, and carbon

*DRAFT Charge to Break-Out Group*

1. What products are presently available that could, with minor editing, contribute to a first (2003) annual report on the state of the ocean? Each product needs to describe:

- The present state
- How it compares with the past

- The confidence/uncertainty in this product

2. What products are presently available that could contribute with marginal improvement? Could these be available by December 2003?

3. What products are missing today that need to be developed to give a complete picture of the ocean's contribution to the state of the climate system?

4. What Expert Teams are needed for evaluation of this part of the system?

> "Subtask 2 - Evaluation: Expert teams of scientists both internal and external to NOAA will be established to continually evaluate the effectiveness of the networks in meeting the performance measures and the adequacy of the deliverables in meeting the system objectives. The expert teams will evaluate analysis/synthesis products, recommend product improvements, recommend where additional sampling is needed or redundancies are not needed, recommend better utilization of existing and new *in situ* and satellite data, and assess the impacts of proposed changes to the system."

- Straw man framework:
    - Seasonal forecasting
    - Decadal forecasting
    - Sea level change
    - Carbon sources and sinks
    - Air-sea exchange of heat and water
    - Ocean heat content and transport, and thermohaline circulation
    - SST
    - Sea Ice

5. What Performance Measures and Metrics are needed to evaluate progress in building the system? The Office of Program Analysis and Evaluation uses this simple litmus test: "So what? Who cares?" In other words, why should the taxpayers buy a multi-million dollar observing system? If they do, how will they know that it is paying off? What should an annual report be striving to deliver?

The best metrics are ones that can be graphed so that progress toward targets can be tracked visually. Examples:

Performance Measure 1: Reduce the uncertainty in projections of sea level rise during the 21st century.

Metric: Range between estimates of sea level rise (centimeters):

| 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|
| 80 cm | 80 cm | 70 cm | 60 cm | 50 cm | 40 cm | 30 cm | 25 cm |

Performance Measure 2: Reduce the uncertainty in estimates of the increase in carbon inventory in the global ocean.

Metric: Uncertainty in estimates of anthropogenic change per decade (Gigatons):

| 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|
| 10 Gt | 10 Gt | 10 Gt | 8 Gt | 8 Gt | 7 Gt | 6 Gt | 4 Gt |

Performance Measure 3: Reduce the error in global measurement of sea surface temperature.

Metric: Estimated error in monthly analysis of sea surface temperature at 500 kilometer resolution (degrees Celsius):

| 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|
| 1.3 C | 1.3 C | 1.0 C | 0.8 C | 0.6 C | 0.5 C | 0.4 C | 0.3 C |

Below are pasted the metrics presently in the Program Plan. Can these be improved to be more consistent with the style above and be more reflective of where we are trying to go with an annual report on the ocean's role in climate?

### *5.2 Document ocean carbon sources and sinks.*

Performance Measure 6: Complete the Northern Hemisphere ocean observing system to assist in determining carbon dioxide sources and sinks over the coterminous United States in partnership with the atmospheric observing system.

Performance Measure 7: Complete the expansion of the global oceanic observing system to inventory global scale oceanic uptake of excess carbon dioxide in partnership with the atmospheric observing system.

Metrics:

- By FY 04, report interhemispheric gradients of $CO_2$ constrained to 1 ppm on seasonal time scales.
- By FY 05, improve measurements of North Atlantic and North Pacific Ocean basin carbon dioxide fluxes to within ±0.2 Pg/C per year.
- By FY 05, reduce uncertainty on regional estimates of carbon sources and sinks on a global basis to ±50%.
- By FY 08, produce seasonal, global carbon source and sink maps on a 5° x 5° grid scale.
- By FY 08, provide publicly available, routine changes in inventory of carbon, heat, and salinity in the ocean basins on a decadal time frame to assess the effect of global change and feedbacks on the ocean

### 5.3 Document heat uptake, transport, and release by the ocean.

Performance Measure 8: For the global tropical ocean belt, complete the upper ocean and surface meteorology observing system needed to measure the variations in ocean heat content and transport, and ocean-atmosphere exchange of heat.

Performance Measure 9: For the global ocean, complete the ocean observing system needed to measure the global variations in sea surface temperature, surface and 2000M circulation, total heat content of the ocean, transport of heat across and between all ocean basins, and ocean-atmosphere exchange of heat.

Metrics:

- By FY 05, for the TAO/TRITON belt of the tropical Pacific (95W-150E, 8N-8S), deliver analyses of monthly mean sea surface temperature and temperature anomaly at 500 km resolution to 0.5°C accuracy, average temperature from 0-450m depth to 0.5°C accuracy, and seasonal average temperature change to 0.5°C per three months.
- By FY 05, at four ocean reference stations, deliver routine annual analyses of ocean-atmosphere flux to 10 W/m2, average temperature at 0-1000m depth to 0.1°C, and seasonal average temperature change to 0.1°C per three months.
- By FY 06, for the entire tropical Pacific (70W-120E, 20N-20S), and for the Pacific Decadal Oscillation core (150E-150W, 35N-45N), and for the PIRATA belt of the topical Atlantic (10N-10S), deliver analyses of monthly mean sea surface temperature anomaly at 500 km resolution to 0.5°C accuracy, average temperature from 0-450m depth to 0.5°C accuracy, and seasonal average temperature change to 0.5°C per three months.
- By FY 06, at 14 ocean reference stations, deliver routine annual analyses of variability in ocean-atmosphere flux to 10 W/m2, average temperature at 0-1000m depth to 0.1°C, and seasonal average temperature change to 0.1°C per three months.
- By FY 08 deliver analyses of the seasonal means of the surface and 2000m ocean velocity fields on appropriate spatial resolutions that capture the major features of the overturning circulation for all the core climate variability regions (the global tropics, Pacific Decadal Oscillation, North Atlantic Oscillation, high latitude water mass formation regions both northern and southern hemispheres).
- By FY 08, for all core climate variability regions (the global tropics, Pacific Decadal Oscillation, North Atlantic Oscillation, high latitude water mass formation regions both northern and southern hemispheres), deliver analyses of monthly mean sea surface temperature anomaly at 500 km resolution to 0.4°C accuracy, average temperature at 0-1000m depth to 0.5°C accuracy, and annual average temperature change to 0.5°C per year.
- By FY 08, at 29 ocean reference stations, deliver routine annual analyses of variability in ocean-atmosphere flux to 10 $W/m^2$, average temperature at 0-1000m depth to 0.1°C, and seasonal average temperature change to 0.1°C per three months.

**5.3 Document the air-sea exchange of water and the ocean's overturning circulation.**

Performance Measure 10: For the global ocean, complete the oceanographic, surface meteorology, and analysis system needed to measure variability in the ocean-atmosphere exchange of fresh water, i.e., precipitation and evaporation.

Performance Measure 11: Design, deploy, and implement instrument and analysis systems to provide long term integrated measures of the global thermohaline circulation and deliver yearly estimates of the state of the thermohaline circulation - intensity, properties, freshwater transport.

Metrics:

- By FY 05 for the global ocean deliver weekly analysis of precipitation at 5°x5° resolution to 5 cm per month accuracy.
- By FY 08 for the global ocean deliver daily analysis of precipitation and evaporation at 2°x5° resolution to 5 cm per month accuracy.

## Group 4: Ocean content and transport of heat, fresh water, and carbon

*DRAFT Charge to Break-Out Group*

1. What products are presently available that could, with minor editing, contribute to a first (2003) annual report on the state of the ocean? Each product needs to describe:
    - The present state
    - How it compares with the past
    - The confidence/uncertainty in this product

2. What products are presently available that could contribute with marginal improvement? Could these be available by December 2003?

3. What products are missing today that need to be developed to give a complete picture of the ocean's contribution to the state of the climate system?

4. What Expert Teams are needed for evaluation of this part of the system?

> "Subtask 2 - Evaluation: Expert teams of scientists both internal and external to NOAA will be established to continually evaluate the effectiveness of the networks in meeting the performance measures and the adequacy of the deliverables in meeting the system objectives. The expert teams will evaluate analysis/synthesis products, recommend product improvements, recommend where additional sampling is needed or redundancies are not needed, recommend better utilization of existing and new *in situ* and satellite data, and assess the impacts of proposed changes to the system."

- Straw man framework:
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    - Decadal forecasting
    - Sea level change
    - Carbon sources and sinks
    - Air-sea exchange of heat and water
    - Ocean heat content and transport, and thermohaline circulation

- SST
- Sea Ice

5. What Performance Measures and Metrics are needed to evaluate progress in building the system? The Office of Program Analysis and Evaluation uses this simple litmus test: "So what? Who cares?" In other words, why should the taxpayers buy a multi-million dollar observing system? If they do, how will they know that it is paying off? What should an annual report be striving to deliver?

The best metrics are ones that can be graphed so that progress toward targets can be tracked visually. Examples:

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Metric: Range between estimates of sea level rise (centimeters):

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|---|---|---|---|---|---|---|---|
| 80 cm | 80 cm | 70 cm | 60 cm | 50 cm | 40 cm | 30 cm | 25 cm |

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Metric: Uncertainty in estimates of anthropogenic change per decade (Gigatons):

| 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|
| 10 Gt | 10 Gt | 10 Gt | 8 Gt | 8 Gt | 7 Gt | 6 Gt | 4 Gt |

Performance Measure 3: Reduce the error in global measurement of sea surface temperature.

Metric: Estimated error in monthly analysis of sea surface temperature at 500 kilometer resolution (degrees Celsius):

| 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|
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Below are pasted the metrics presently in the Program Plan. Can these be improved to be more consistent with the style above and be more reflective of where we are trying to go with an annual report on the ocean's role in climate?

### *5.2 Document ocean carbon sources and sinks.*

Performance Measure 6: Complete the Northern Hemisphere ocean observing system to assist in determining carbon dioxide sources and sinks over the coterminous United States in partnership with the atmospheric observing system.

Performance Measure 7: Complete the expansion of the global oceanic observing system to inventory global scale oceanic uptake of excess carbon dioxide in partnership with the atmospheric observing system.

Metrics:

- By FY 05, reduce uncertainty on regional estimates of carbon sources and sinks on a global basis to ±50%.
- By FY 05, for the North Atlantic Ocean report the change in ocean carbon inventory over the last decade constrained to 2 Pg/C per year.
- By FY 07, for the North Pacific Ocean report the change in ocean carbon inventory over the last decade constrained to 2 Pg/C year
- By FY 08, produce seasonal, global carbon source and sink maps on a 5° x 5° grid scale.
- By FY 08, provide publicly available, routine changes in inventory of carbon, heat, and salinity in the ocean basins on a decadal time frame to assess the effect of global change and feedbacks on the ocean.

**5.3 Document heat uptake, transport, and release by the ocean.**

Performance Measure 8: For the global tropical ocean belt, complete the upper ocean and surface meteorology observing system needed to measure the variations in ocean heat content and transport, and ocean-atmosphere exchange of heat.

Performance Measure 9: For the global ocean, complete the ocean observing system needed to measure the global variations in sea surface temperature, surface and 2000M circulation, total heat content of the ocean, transport of heat across and between all ocean basins, and ocean-atmosphere exchange of heat.

Metrics:

- By FY 05, for the TAO/TRITON belt of the tropical Pacific (95W-150E, 8N-8S), deliver analyses of monthly mean sea surface temperature and temperature anomaly at 500 km resolution to 0.5°C accuracy, average temperature from 0-450m depth to 0.5°C accuracy, and seasonal average temperature change to 0.5°C per three months.
- By FY 05, at four ocean reference stations, deliver routine annual analyses of ocean-atmosphere flux to 10 $W/m^2$, average temperature at 0-1000m depth to 0.1°C, and seasonal average temperature change to 0.1°C per three months.
- By FY 06, for the entire tropical Pacific (70W-120E, 20N-20S), and for the Pacific Decadal Oscillation core (150E-150W, 35N-45N), and for the PIRATA belt of the topical Atlantic (10N-10S), deliver analyses of monthly mean sea surface temperature anomaly at 500 km resolution to 0.5°C accuracy, average temperature from 0-450m depth to 0.5°C accuracy, and seasonal average temperature change to 0.5°C per three months.
- By FY 06, at 14 ocean reference stations, deliver routine annual analyses of variability in ocean-atmosphere flux to 10 $W/m^2$, average temperature at 0-1000m depth to 0.1°C, and seasonal average temperature change to 0.1°C per three months.

- By FY 08 deliver analyses of the seasonal means of the surface and 2000m ocean velocity fields on appropriate spatial resolutions that capture the major features of the overturning circulation for all the core climate variability regions (the global tropics, Pacific Decadal Oscillation, North Atlantic Oscillation, high latitude water mass formation regions both northern and southern hemispheres).
- By FY 08, for all core climate variability regions (the global tropics, Pacific Decadal Oscillation, North Atlantic Oscillation, high latitude water mass formation regions both northern and southern hemispheres), deliver analyses of monthly mean sea surface temperature anomaly at 500 km resolution to 0.4°C accuracy, average temperature at 0-1000m depth to 0.5°C accuracy, and annual average temperature change to 0.5°C per year.
- By FY 08, at 29 ocean reference stations, deliver routine annual analyses of variability in ocean-atmosphere flux to 10 $W/m^2$, average temperature at 0-1000m depth to 0.1°C, and seasonal average temperature change to 0.1°C per three months.

**5.3 Document the air-sea exchange of water and the ocean's overturning circulation.**

Performance Measure 11: Design, deploy, and implement instrument and analysis systems to provide long term integrated measures of the global thermohaline circulation and deliver yearly estimates of the state of the thermohaline circulation - intensity, properties, freshwater transport.

Metrics:

- By FY 06, for the sinking regions of the north Atlantic and southern hemisphere, deliver annual estimates of the five-year average temperature and salinity of the intermediate, deep, and bottom waters to 0.05°C and 0.05PSU.
- By FY 06, across zonal sections in the Atlantic at 24N, 47N, and 35S, deliver estimates of the average annual meridional heat transport from surface to bottom at 0.5PWatt accuracy.
- By FY 08, for the sinking regions of the north Atlantic and southern hemisphere, deliver yearly estimates of the annual average temperature and salinity of the intermediate, deep, and bottom waters to 0.03°C and 0.03PSU.
- By FY 08, across zonal sections in the Atlantic at 24N, 47N, and globally at 35S, deliver estimates of the average annual meridional heat transport from surface to bottom at 0.3PWatt accuracy.

**Appendix D.4: Working Group Initial Reports**

To view the workshop report presented by each working group, click on the title of the group below.

Working Group 1: Report structure

Working Group 2: Sea level

Working Group 3: Air-sea exchange of heat, water, carbon

Working Group 4: Ocean content and transport of heat, water, carbon

**Appendix E: Climate Observing System Council (COSC)**

The Climate Observing System Council reviews the Climate Observation Program's contribution to the international Global Climate Observing System to recommend effective ways for the Program to respond to the long-term observational needs of the Operational Forecast Centers, International Research Programs, and major Scientific Assessments. The Council meets at least annually and is comprised of members both internal and external to NOAA who individually offer their expert advice. The term of membership is two years with a renewal option for two additional terms.

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**Appendix F: List of Acronyms**

# List of Acronyms

AOML Atlantic Oceanographic and Meteorological Laboratory
ARCs Applied Research Centers
ARPEGE-CLIMAT Climate Research Project on Small and Large Scales (France)
BMRC Bureau of Meteorology Research Centre (Australia)
BoM Bureau of Meteorology (Australia)
C&GC Climate and Global Change
CCRI Climate Change Research Initiative
CCSP Climate Change Science Program
CDC Climate Diagnostics Center
CICOR Cooperative Institute for Climate and Ocean Research
CIMAS Cooperative Institute for Marine and Atmospheric Studies
CIRES Cooperative Institute for Research in Environmental Sciences
CLIPS Climate Information and Prediction Services Project
COLA Center for Ocean, Land, and Atmosphere Studies
CORC Consortium on Ocean's Role in Climate
COSC Climate Observing System Council
COSP Climate Observations and Services
CLIVAR Climate Variability and Predictability Program
CPC Climate Prediction Center
CPRDB Comprehensive Pacific Raingauge Database
CSIRO Commonwealth Scientific and Industrial Research Organization
DAC Data Assembly Center
DBCP Data Buoy Cooperation Panel
DMC Drought Monitoring Center
DWBC Deep Western Boundary Current
ECMWF European Centre for Medium-Range Weather Forecasts
ENSO El Niño-Southern Oscillation
EVAC Environmental Verification and Analysis Center
FSU-COAPS Florida State University Center for Ocean-Atmosphere Prediction Studies
GCC Global Carbon Cycle
GCOS Global Climate Observing System
GCTE Global Change and Terrestrial Ecology Program
GCRMN Global Coral Reef Monitoring Network
GDC Global Drifter Center
GLOSS Global Sea Level Observing System
GODAE Global Ocean Data Assimilation Experiment
GOOS Global Ocean Observing System
GPCP Global Precipitation Climatology Project
HURDAT Atlantic Basin Hurricane Database
IAI Inter-American Institute for Global Change Research
IOC Intergovernmental Oceanographic Commission
IRI International Research Institute for Climate Prediction

ITCZ Inter-Tropical Convergence Zone
JCOMM Joint Technical Commission for Oceanography and Marine Meteorology
JIMAR Joint Institute for Marine and Atmospheric Research, University of Hawaii
JIMO Joint Institute for Marine Observations
JMA Japan Meteorological Agency
NAO North Atlantic Oscillation
NCDC National Climatic Data Center
NCEP National Centers for Environmental Prediction
NEAR-GOOS North-East Asian Regional GOOS
NESDIS National Environmental Satellite, Data, & Information Service
NGO non-government organization
NIC National Ice Center
NIH National Institutes of Health
NMHS National Meteorological and Hydrological Services
NMRI Naval Medical Research Institute
NOAA National Oceanic and Atmospheric Administration
NODC National Oceanographic Data Center
NWS National Weather Service
NWS-PR National Weather Service Pacific Region
OGP Office of Global Programs
OOPC The Ocean Observations Panel for Climate
PACIS Pan-American Climate Information System
PDO Pacific Decadal Oscillation
PEAC Pacific ENSO Applications Center
PMEL Pacific Marine Environmental Laboratory
PNNL Pacific Northwest National Laboratory
RRP ENSO Rapid Response Project
RVIB Research Vessel / Ice Breaker
SCPP Seasonal-to-Interannual Climate Prediction Program
SEARCH Study of Environmental Arctic Change
SIO-ECPC Scripps Institution of Oceanography-Experimental Climate Prediction Center
SOOP Ship-of-Opportunity Program
SOI Southern Oscillation Index
SPARCE South Pacific Rainfall Climate Experiment
SRDC Surface Reference Data Center
SSG Scientific Steering Group
SST Sea Surface Temperature
START Global Change System for Analysis, Research, and Training
SURFRAD Surface Radiation Budget Network
TAO Tropical Atmosphere Ocean Array
TOGA Tropical Oceans-Global Atmosphere Program
TRMM Tropical Rainfall Measuring Mission
UNCED United Nations Conference on Environment and Development
UNFCCC United Nations Framework Convention on Climate Change
UOTC Upper Ocean Thermal Center
USIABP U.S. Interagency Arctic Buoy Program

USGCRP U.S. Global Change Research Program
VOS Voluntary Observing Ships
WCRP World Climate Research Program
WHO World Health Organization
WHOI Wood's Hole Oceanographic Institution
WMO World Meteorological Organization
WWW The World Weather Watch of WMO
XBT Expendable Bathythermograph